International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 10, Issue 2, Apr 2020, 297–304

PREPARATION AND RHEOLOGICAL ANALYSIS OF MR FLUIDS

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ABSTRACT

In this paper, the detailed procedure for the preparation and rheological analysis of MR (Magneto-Rheological) fluids is detailed. Three MR fluid samples were prepared using a carrier fluid (silicon oil) which is mixed with Fe particles in addition to additive grease. The grease also serves the purpose of a coating material for the Fe particles. The samples were prepared in-house using an experimental set-up. The sedimentation analysis of fluid samples was done along with off state testing of fluids for its rheological properties. MR fluids are special nature of fluids which are mainly used for vibration control, in which changes in magnetic fields result into drastic changes in yield stress. This change is entirely reversible which is very quick, as it depends entirely on the value of magnetic field.

KEYWORDS: MR Fluid, Rheological Properties, Sedimentation & Magnetic Field

Received: Jan 24, 2020; **Accepted**: Feb 04, 2020; **Published**: Mar 04, 2020; **Paper** Id.: IJMPERDAPR202026

Original Article

INTRODUCTION

The magnetisable particles (Fe) having size in microns, when suspended in a carrier fluid forms the magneto-rheological fluids. The behaviour of the MR fluid changes when magnetic field passes through it. The Fe particles start aligning as per the power of the magnetic field thereby forming a recognizable pattern. This formally results in the conversion of fluid into a semi-solid substance. Jacob Rabinow at the US National Bureau of Standard in the late 1940s developed the MR fluid [1].

As shown in the figure 1, the Fe particles starts making a pattern and finally in the form of lines according to the intensity of the applied magnetic field. As the magnitude of magnetic field increases, the behaviour of the fluid changes from Newtonian to non- Newtonian with a significant variation in viscosity as well as yield stress. This variation is entirely reversible and solely relying on the value of the applied field. A number of articles have been published on the properties and applications of MR fluids [2-9]. In automotive sector, MR fluid is used in semi-active dampers for vibration control. The semi-active dampers provide much more comfort to the passengers as compared to the traditional hydraulic shock absorbers [10]. MR fluids also find its applications in brakes, clutches, civil engineering areas i.e. earthquake, bridges and even in bio-medical areas etc [11, 12].

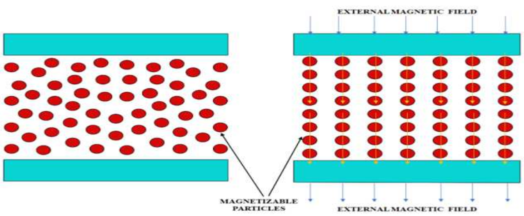

Figure 1: MR Fluid in (a) Absence of Magnetic Field (b) Presence of Magnetic Field

PREPARATION OF MR FLUID

Typically an MR Fluid contains up to 50 percent in volume of the magnetisable particles [13] with remaining percentage appropriately split between the carrier fluid i.e. mineral oil or silicon oil etc. and the additives i.e. grease or oleic acid and many more. Carrier fluid is usually a non-magnetisable fluid where as the additives vary over a wide range as the researchers are working to find the most suitable additive for the MR fluid. The additives serve a major role in the working of a MR fluid as they not only prevent the sedimentation of the Fe particles but also help in preventing the oxidation of the Fe particles. After doing the literature survey and market availability of components, three different MR fluid samples having varying compositions of constituents were prepared (table 1 & 2) using micro-iron powder (300 mesh), low viscosity silicon oil (50 cST) as the carrier fluid & grease (special type) as the additive an is as shown below:

Table 1: MR Fluid Composition in Volume %

MRF Sample	Fe	Silicon Oil	Grease
A	15	75	10
B	20	68	12
C	25	60	15

Table 2: MR Fluid Composition in Weight %

MRF Sample	Fe (wt. %)	Silicon Oil (wt. %)	Grease (wt. %)
A	59.36	36.07	4.57
B	65.57	29.88	4.55
C	73.47	21.44	5.09

The MR fluid samples were prepared (Figure 2) using equipments like mechanical stirrer, weighing scale having suitable range, non-sticky utensil (for carrying fluid) etc, as shown in Figure 3 (a)-(e).

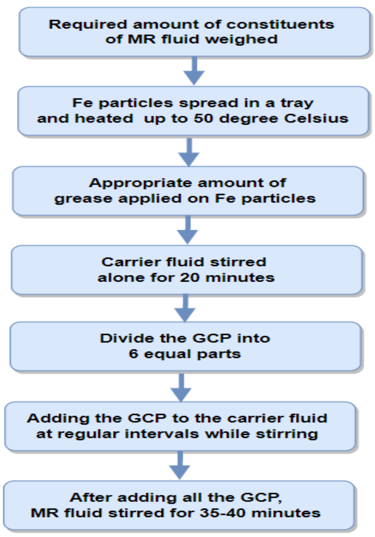

Figure 2: Procedure for Preparation of MR Fluid Sample.

The steps for the preparation of each MR Fluid sample are given below:

- Required amounts of constituents i.e. Fe particles, silicon oil and white lithium grease were weighed according to

the table 1 and 2 and sorted in different containers.

- Fe particles were spread in a tray and heated up to 50˚C.
- Weighed amount of grease is applied on iron particles spread in tray with the help of a brush.
- The carrier fluid i.e. silicon oil is firstly stirred alone using the stirrer for 20 minutes.
- Dividing the required amount of grease-coated Fe powder into 6 equal parts as shown in figure 3
- Adding the Grease-Coated-Powder (GCP) to the fluid under stirrer part-by-part at regular intervals of 15 minutes while stirring continues.
- After adding all the powder, the fluid is stirred for 35-40 minutes for the final round.
- The fluid samples are viscous fluids with dark greyish or almost black color. The same procedure is employed for the synthesis of the three fluid samples A, B and C.

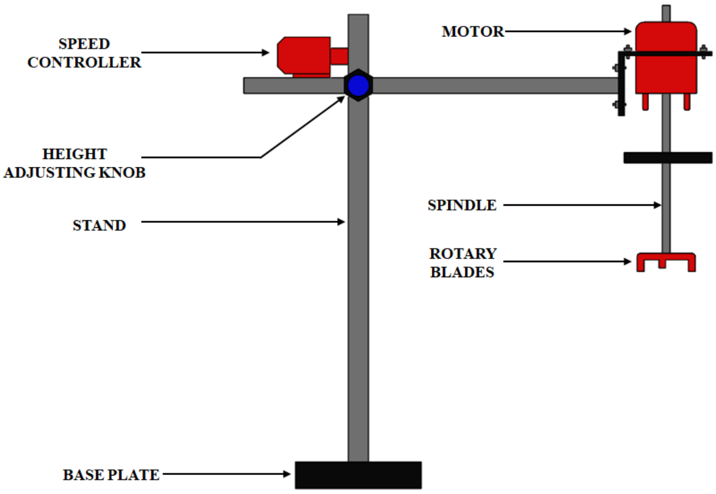

Figure 3(a): Mechanical Stirrer.

Figure 3(b): Silicon Oil Being Stirred.

Figure 3(c): Grease-Coated Fe Powder.

Figure 3(d): Stirring of MR Fluid Sample

Figure 3(e): Prepared MR Fluid Sample.

ANALYSIS OF THE MR FLUID SAMPLES

The main issue which needs to be addressed while preparing MR fluid is settling of Fe particles. This can be checked using the sedimentation test of the fluid samples. Sedimentation is basically the settling of particles as there is difference in density of the constituent materials of the fluid. In this case, the sedimentation test was performed without applying the magnetic field on the MR fluid. During the test, the Fe particles start settling down, thereby resulting in the creation of visually clearer layer of fluid at the top termed as supernatant fluid. The supernatant fluid height increases with respect to the change in time as sedimentation continues. The boundary between the supernatant fluid and the lower fluid is called as mud-line. The sedimentation test was carried in-house using the holding set-up as shown in Figure 4.

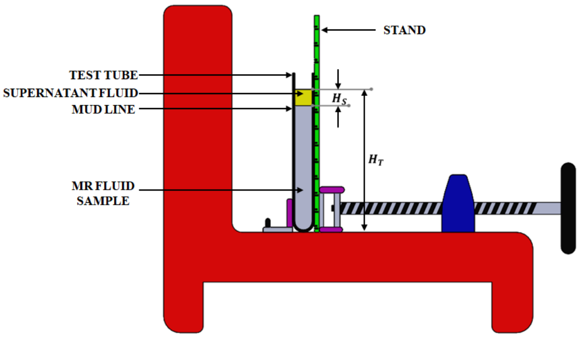

Figure 4: Setup to Find Out Sedimentation Ratio.

Figure 5(a): Test Tube and Ruler Arrangement.

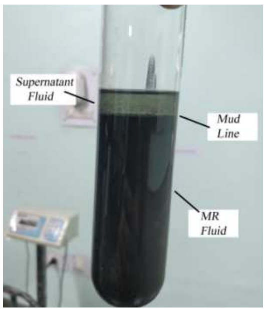

Figure 5(b): Test Tube Showing Various Fluid Layer.

The MR fluid as shown in figure 5 (a) & (b) were placed in a well-lit room and the test was performed by filling the test tube with MR Fluid samples A, B and C up to 10 cm and it was mounted with a ruler on the setup. Measurements were recorded for the height of supernatant fluid (H_S) after regular intervals of 5 minutes as per [13] and total height of fluid in the glass tube was also recorded to calculate the sedimentation ratio (S.R.) which is given by the ratio of height of supernatant oil to the total height of fluid in the tube. Mathematically,

$$\text{S.R.} = \frac{H_S}{H_T} \times 100\%$$

where, S.R. is the sedimentation ratio, H_S is the height of supernatant fluid and H_T is the total height of fluid filled in the tube.

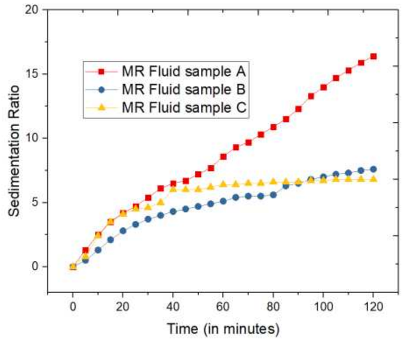

Figure 6: Time vs Sedimentation Ratio.

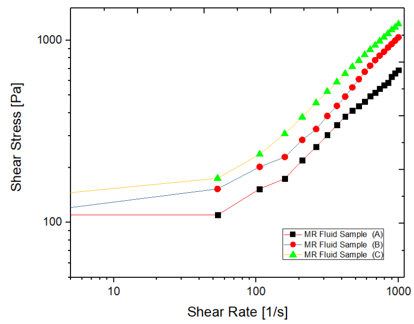

Figure 7: Shear Stress vs Shear Rate

From the sedimentation graph, (figure 6), it can be observed that MR fluid sample A has higher sedimentation ratio with respect to MR fluids samples B and C. The amount of grease used in MR fluid sample A is 10% (in volume) as compared to the grease content of 12% (in vol.) and 15% (in volume) of fluid samples B and C respectively. From this, it can be said that the grease plays a vital role on the sedimentation ratio of such type of fluids. The graph also predicts that by enhancing the percentage of grease, sedimentation ratio may be controlled but upto a certain extent.

Figure7 shows the shear stress versus the shear rate for the fluid samples. The MR fluid shows a non-newtonian character when magnetic field is not existent. The figure shows that with an increase in shear rate, the shear stress of the MR fluid increase. MR Fluid sample C shows the highest shear stress among all three samples which is due to presence of higher percentage of Fe particles in the fluid.

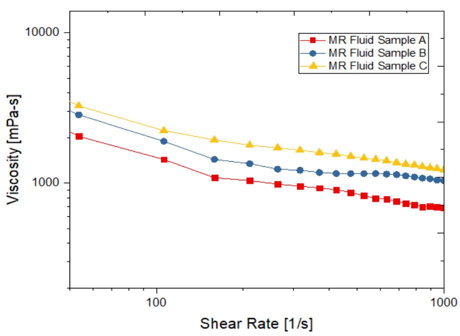

Figure 8: Viscosity vs Shear Rate for MR Fluid Sample A, B and C.

Figure 8 represent the values of viscosity for shear rates for all three MR fluid samples. The phenomenon of shear thinning is also depicted in this figure as there is gradual decrease in dynamic viscosity of prepared fluid samples with an increase in shear rate. It can be observed that MR Fluids exhibit Non-Newtonian behaviour when no magnetic field is present. When shear rate is increased, there is a fall in the viscosity of the samples.

CONCLUSIONS

In this article, MR fluids having Fe particles coated with grease were developed and sedimentation test of the prepared MR fluids was done. Anton Paar, (Panjab University facilities) were used to study the rheological properties of the prepared fluid samples in the absence of magnetic field. In this, shear stress versus shear rate and viscosity versus shear rate for MR fluid samples was studied. It can be concluded that in order to reduce the sedimentation and improve the properties of the MR fluid, it is important to weigh the benefit and drawbacks caused by the grease which is used as a coating for the Fe particles.

REFERENCES

1. *Rabinow, J. (1948). The magnetic fluid clutch. Electrical Engineering, 67(12), 1167-1167.*
2. *Jolly, M. R., Bender, J. W., & Carlson, J. D. (1999). Properties and applications of commercial magnetorheological fluids. Journal of intelligent material systems and structures, 10(1), 5-13.*
3. *Turczyn, R., & Kciuk, M. (2008). Preparation and study of model magnetorheological fluids. Journal of Achievements in Materials and Manufacturing Engineering, 27(2), 131-134.*
4. *Zhang, J. Q., Zhang, J., & Jing, Q. (2009). Effect of seven different additives on the properties of MR fluids. In Journal of Physics: Conference Series (Vol. 149, No. 1, p. 012086). IOP Publishing.*
5. *Spaggiari, A. (2013). Properties and applications of Magnetorheological fluids. Frattura ed Integrità Strutturale, 7(23), 48-61.*
6. *Kumar, S. M. A. (2015). Experimental studies of in-house developed magnetorheological fluid in a damper. International Journal of Performability Engineering, 11(3), 257-264.*
7. *Kumbhar, B. K., Patil, S. R., & Sawant, S. M. (2015). Synthesis and characterization of magneto-rheological (MR) fluids for MR brake application. Engineering Science and Technology, an International Journal, 18(3), 432-438.*
8. *Zhang, P., Lee, K. H., & Lee, C. H. (2016). Friction behavior of magnetorheological fluids with different material types and magnetic field strength. Chinese Journal of Mechanical Engineering, 29(1), 84-90.*
9. *Ganesha, A., & Murthy, A. A. (2019). Flux deviating technique to enhance the total magnetic flux density in the fluid flow gap of a monotube single coil MR damper. International Journal of Mechanical and Production Engineering Research and Development, 9(3), 745-752.*
10. *Desai, R. M., Jamadar, M. E. H., Kumar, H., Joladarashi, S., Rajasekaran, S. C., & Amarnath, G. (2019). Evaluation of a commercial MR damper for application in semi-active suspension. SN Applied Sciences, 1(9), 993.*
11. *Ahamed, R., Choi, S. B., & Ferdaus, M. M. (2018). A state of art on magneto-rheological materials and their potential applications. Journal of Intelligent Material Systems and Structures, 29(10), 2051-2095.*
12. *Suarez, A., & Bapat, S. Design and Experimental Analysis of a Biomedical Prosthetic Knee with Magnetorheological Fluid. In ASME 2015 Conference on Smart Materials, Adaptive Structures and Intelligent Systems. American Society of Mechanical*

Engineers Digital Collection.

13. *Mangal, S. K., Kataria, M., & Kumar, A. (2013). Synthesis of magneto rheological fluid. International Journal of Engineering and Advanced Technology, 2(6), 20-25.*

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